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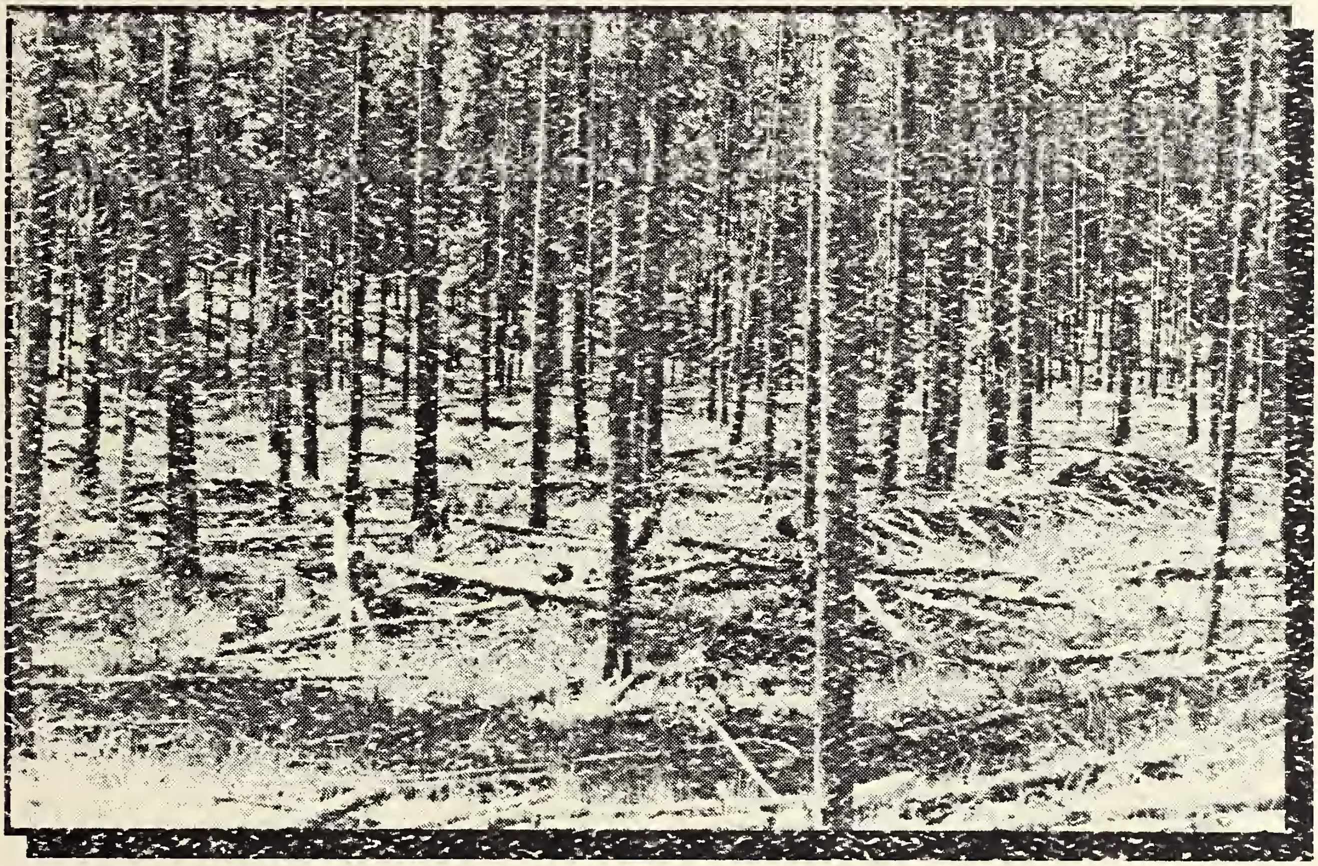

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FORESTRY RESIDUE AVAILABILITY IN MONTANA 1986 - 2000

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Forest Residue Availability in Montana, 1990-2000
Executive Summary

For this report, forest residue, the wood fiber that is not recovered from commercial forest lands because of economic constraints, was analyzed in the following components:

- * Dead wood and cull green material remaining after recent commercial logging.
- * Wood fiber remaining from commercial logging operations more than one year old.
- * Wood fiber cut and left on site following timber stand improvement practices, such as thinning overstocked timber stands, or timber stand conversion operations.
- * Dead trees, small suppressed trees, and cull green trees on commercial timberland that are not scheduled for harvesting or timber stand improvement.
- * Wood fiber on noncommercial timberlands.

Forest land managers believe that more wood fiber has been removed from forest lands in recent years than was removed 5 or more years ago. The volume of forest residue available for energy will decrease in the next decade primarily due to:

- Greater competition for wood fiber by existing industries.

- Greater limits placed on what can be taken from the forest because of changes in timberland management practices. More wood fiber will be left on the logging sites for uses such as nutrient recycling, wildlife habitat enhancement, water quality protection, air quality improvement, and visual satisfaction.

Each component of forest residue was analyzed. Logging residue appears to offer the greatest opportunity to recover additional material. Availability and cost were evaluated on the basis of two recovery systems: log-length recovery and whole-tree recovery (see Table A). Residue recovered by the log-length recovery method, the most common method in Montana, ranged in cost from $60 (tractor systems) to $80 (cable systems) per oven dry ton (ODT), 1990 dollars. The whole tree recovery method had a recovery cost of $25 to $55/ODT with an average of $45/ODT, 1990 dollars.

Table A.

Estimated Annual Amount of Logging Residue Montana

	1986-1990 Average		1991-2000 Projected AveX Estimates	
	Timber Harvested Annually MMBF[b] Scribner	Residue Available Annually Thousands of ODT	Timber Harvested Annually MMBF[b] Scribner	Residue Available Annually Thousands of ODT
Log-length Recovery Method[a]				
Lodgepole Pine	330	81	202	67
Other species	901	113	755	94
Total	**1,231**	**194**	**957**	**161**
Whole Tree Recovery Method	1,231	557	957	433

[a] Economically recoverable residue in pieces greater than 8 feet in length, 4 cubic feet in volume and greater than 40 percent sound.

[b] Millions of board feet.

The analysis showed that logging slash from previous years (more than one year old) would not be a major source of wood fiber because it was in poor condition and expensive to recover. High recovery costs of wood fiber on noncommercial timberlands would also eliminate this material as a major source of fuel or fiber.

The total residue potential from land conversion and pre-commercial thinning in Montana was estimated at over 2 million tons of wood fiber. About 110,000 tons might be produced annually, in northwestern Montana, for the next 20 years at $47.50 per ODT (1990 dollars), but nontimber concerns would limit availability.

Timber on commercial timberlands killed by the mountain pine beetle represents more than 8 million ODT (3 billion board feet, Scribner) of wood fiber. At present recovery rates, less than 1/3 of the 8 million ODT is expected to be harvested by 1995, by which time its potential for lumber would be greatly reduced. Fires of the late 1980s killed hundreds of thousands of acres of timber. No one has estimated the amount or availability of this timber. However, this timber could provide a source of wood fiber for fuel, though nontimber concerns will greatly limit the use of this dead wood.

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Forest Residue Availablility in Montana 1986-2000

Introduction

Timberlands in Montana hold large quantities of wood fiber that are available for harvesting. There are two main reasons why some of this material is not used: 1. it is left on site to protect non-timber resources, and 2. it is uneconomical to harvest. Material that is not used because of economic constraints is categorized as forest residue. Forest residue may be used as a source of fuel for industry or power generation if there is sufficient quantity, adequate access, and low recovery costs. For purposes of this analysis, forest residue components are defined as:

1. Logging residue remaining after recent logging (areas logged in the previous 12 months) consisting of dead wood fiber and cull green wood fiber.
2. Wood fiber cut and left on site following timber stand improvement practices, such as thinning overstocked timber stands, or timber stand conversion operations.
3. Wood fiber remaining from past logging operations (more than one year old).
4. Dead trees, small suppressed trees, and cull green trees on sites that are not scheduled for commercial harvesting or timber stand improvement.
5. Wood fiber on noncommercial timberlands.

The purpose of this study is to identify the gross volume of forest residue, the cost range to recover forest residue, and major trends affecting the future availability of forest residue in Montana.

Specifically this report includes:

1. A discussion of the policies of major landowner groups related to the removal of forest residue;
2. The 1986 - 1990 estimate of the cost and available volumes of forest residue in Montana, in tabular form;
3. Expected changes in sources of wood residue used by wood residue processors; and
4. A 10-year projection of available forest residue.

This study uses the standard reporting groups of counties used by the Montana Department of State Lands in its Inventory Systems, illustrated in Figure 1. It also examines the potential of these zones to supply forest residue to potential users.

Estimates of Forest Residue Availability.

This report updates estimates of logging residue availability done in 1988 for the Montana Department of Natural Resources (Keegan and Hearst 1988). The forest residue estimates developed in 1988 were based on residue volume factors that were applied to the amount of timber being harvested or the amount of land available for treatment. Cost estimates were based on a cost model for recovering forest residue in the Northern Rocky Mountains (Jackson et al. 1984).

The timber harvest data were updated based on the reported 1986-1990 timber harvest (U.S. Forest Service 1991). A recent timber supply study was used to project timber harvest volumes for the period 1991-2000 (Flowers 1992). These results were used to project the available volume of logging residue.

No formal comprehensive update is available for any of the estimates of forest residue volume factors or harvesting costs. The authors updated harvesting costs using the Producers Price Index. To update forest residue volume estimates, the authors conducted detailed interviews with land managers to determine how the volume of available residue material has changed during the past decade and how it might change in the future.

Forest Residue Volumes — Market Impacts and Policies of Major Landowner Groups.

For this report, interviews were conducted with the following forest land managers:

* **Dave Spores**, Director of Timber Management, U.S. Forest Service, Region One, Missoula, Montana.

* **Charles (Chuck) Spoon**, Deputy Supervisor - Resource Programs, Lolo National Forest, Missoula, Montana.

* **Warren Illi**, Deputy Supervisor - Resource Coordination, Flathead National Forest, Kalispell, Montana.

* **Kenneth A. Briggeman**, Staff Officer, Timber, Kootenai National Forest, Libby Montana.

* **Jeff Jahnke**, Deputy State Forester, Montana Department of State Lands, Division of Forestry, Missoula, Montana.

* **Gordon Sanders**, Logging and Procurement Manager, Missoula Area Operations, Champion International Corporation, Missoula, Montana.

* **Bob Boeh**, Director Log Procurement and Planning, Plum Creek Timberlands, Columbia Falls, Montana.

Individuals interviewed have direct responsibility for the management of much of the commercial timberland in Montana; the lands under their jurisdiction produced over 70 percent of the timber harvested in the state during the 1980s.

The land managers were unanimous in their opinion that more forest residue was removed from forest lands in recent years than was removed five to ten years ago. This added volume has come from the removal of wood fiber that does not meet contract merchantability specifications because it is too small in diameter or contains too much defect.

These same land managers expect that the volume of forest residue will decrease in the next decade because of increasing competition for this material by existing industries.

There also is a strong feeling that greater limits will be placed on what can be taken from the forest as changes in land management philosophies give greater consideration to non-timber resources. Examples include the U.S. Forest Service ecosystem approach to timberland management, or Plum Creek Timberland's "Environmental Forestry." New approaches to timberland management, both public and private, will leave more wood and wood residues on the logging sites for nutrient recycling, wildlife habitat enhancement, water quality protection, air quality improvement, and visual satisfaction.

Also, a greater proportion of the harvest on industrial private lands in particular, will be re-entry to sites that have been harvested in the past. These re-entry logging operations produce less logging residue per unit volume of sawtimber harvested.

The land managers felt there would be less timber stand improvement work, such as precommercial thinning, in the future. At the same time the opinion was that major users of mill residue, particularly the pulp and paper industry, will be turning more and more to forest residue in response to decreases in the volumes of timber processed by sawmills and plywood plants, and the resulting decreases in mill residue.

A summary of the responses from forest land managers follows:

> *The U.S. Forest Service expects that changing silvicultural prescriptions will restrict to a much greater degree, what can be taken from logging sites. Visual effects and wildlife security cover protection will play a big part in future timber harvesting prescriptions. There will be more biomass retention on the harvested sites; logging methods will leave unmerchantable material at the stump rather than on log landings. A number of managers indicated that the requirements will be to leave substantially more large dead woody material than in the past.*
>
> *A minor exception is that the U.S. Forest Service currently is requiring YUM, the yarding of unmerchantable material, on a limited basis. This involves bringing some unmerchantable material to the log landing and decking it for potential users. If markets are not available, the purchaser would not be required to remove the material from the log landings.*
>
> *The Montana Department of State Lands (DSL) expects less drastic changes in the way it will conduct forest management during the next ten years. DSL expects there will be a greater demand for the material offered for sale during the next ten years. DSL has very limited resources for pre-commercial timber stand improvements such as thinning.*
>
> *The two largest private industrial forest land owners in the state, Champion International Corporation and Plum Creek Timberlands, expect a slow reduction in the volume of wood residues that will be available for harvest over the next ten years. Their reasons are the same as for the public forest lands: 1) more material will be left on the logging sites for nutrient recycling, water quality protection, air quality improvement, wildlife protection and, to a lesser extent, the visual impact of harvesting operations, and 2) increased demand for material that can be used for solid wood products, such as lumber, and as chips for pulp and paper.*

The land managers agreed unanimously that less forest residue would be available in the future than the 1988 estimates indicated. This is due to increased demand for material formerly left in the woods, and to requirements by forest land managers that more wood fiber be left on the logging sites. Based on the results of these interviews, the authors suggest that the residue volumes presented in this report should be viewed as optimistic estimates.

The forest residue recovery methods considered in this study are described as follows:

Logging Residue and Approaches to Recovery

Logging residue appears to offer the greatest opportunity to recover additional material; consequently, the analysis of this component received the most attention. Logging residue availability and cost was evaluated on the basis of two recovery systems.

Log-Length Recovery Method

A log-length residue recovery system would recover large dead or cull green trees and log-length cull portions of merchantable trees. This would be done in conjunction with normal sawlog harvesting and would involve virtually no change in most harvesting operations. This system would require loading and hauling dead and green material directly to the mill site where the cull portions would be separated.

Whole-Tree Recovery Methods

The recovery of submerchantable stems and limbs and unmerchantable bole tips of sawtimber trees requires a whole-tree logging system. There are typically two approaches to this type of recovery — in-woods processing OR processing at the mill sites. Both approaches require the skidding of the whole tree (branches and top intact) to the landing. With the in-woods processing system, the limbs, tops, and submerchantable stems are separated from the merchantable stems at the landing. Mill site processing involves loading the whole trees onto logging trucks and removing cull material and waste at the mill. The advantages and disadvantages of each approach are discussed in detail in the next section.

Characteristics of Material Left After Logging.

An inventory of logged-over lands was conducted for the state and for northwestern Montana (Howard and Fiedler 1984, Keegan et al. 1987). The focus of the inventory was on material potentially recoverable in a log-length harvesting operation, a system widely used in Montana.

The inventory indicated that large volumes of wood fiber of widely varying condition, class, and size are left on logged-over areas. The net volume of wood residue, in pieces at least 1 foot long with a small-end diameter larger than 3 inches (the smallest piece measured in the inventory), exceeded 100 cubic feet per thousand board feet (Scribner Decimal C) of sawtimber harvested.

The estimated board-foot-to-cubic-foot conversion factor for sawtimber (sawlogs and veneer logs) in Montana is 4.8 board feet per cubic foot (Keegan et al. 1983). Based on this factor, 1,000 board feet (Scribner Decimal C) would contain 208 cubic feet. The inventory indicated, therefore, that an estimated net residue volume equivalent to nearly 50 percent of the sawtimber volume harvested remains on the logging sites in pieces of wood longer than 1 foot and with a small-end diameter greater than 3 inches.

The annual sawtimber harvest in the state has averaged approximately 1,231 million board feet (Scribner Decimal C) for the period 1986-1990, or about 255 million cubic feet. This harvest produces approximately 120 million cubic feet of logging residue annually.

Estimates of Logging Residue Reasonably Recoverable in Log-Length Operations

All 120 million cubic feet of residue is economically recoverable if market prices are high enough. Not all is recoverable at a price that would be considered reasonable for present uses.

Piece Size and Recovery Costs

The volume of usable wood per piece is a major determinant of the costs of recovering logging residue. Usable wood is determined by piece size and condition.

Two criteria, one for piece size and one for soundness, were used to identify the volume of logging residue that is recoverable within a reasonable cost range. First, it was assumed that a piece had to be 8 feet long to be recoverable as a separate piece. Second, it was assumed that any piece less than 40 percent sound would not be worth recovering. After the adjustment for soundness, it was assumed that any piece with a net volume, including bark, of less than 4 cubic feet would not be economically recoverable.

The soundness criterion was developed on the basis of discussions with a number of individuals who have been harvesting non-sawtimber wood. The piece size guideline was based on the logging residue cost model that was developed by the Bureau of Business and Economic Research (Jackson et al. 1984). The soundness and piece size cutoffs are somewhat arbitrary, but the individuals contacted considered the limits to be reasonable and conservative.

Because previous analysis indicated substantial differences in residue per unit volume of timber harvested on lodgepole pine forests types compared to other forest types, separate estimates of residue volume were made for lodgepole pine (Keegan and Hearst 1988).

Table 1 indicates the effect of the adjustment for soundness and piece size. Column 1 indicates, by category, the net wood residue and bark volume for all wood fiber material with a small-end diameter greater than 3 inches. Column 2 shows the combined net wood residue and bark volumes for material more than 40 percent sound. In both categories more than 90 percent of the net wood fiber was in pieces greater than 40 percent sound. Column 3 indicates, however, that only a small portion of the material greater than 40 percent sound is large enough to be removed at a reasonable cost.

In the non-lodgepole pine category, each thousand board feet (Scribner Decimal C) of sawtimber harvested had an estimated 12 cubic feet of net wood residue — greater than 40 percent sound, in pieces 4 cubic feet or larger, and more than 8 feet long. The lodgepole pine category had a very low volume of residue in large pieces, with only 4 cubic feet per thousand board feet remaining after logging.

Given these constraints of soundness and piece size, an estimated 15,569,000 cubic feet of logging residue would be available annually in Montana through the log-length recovery system. This equals 194,000 oven dry tons of wood fiber. The estimates of the volumes available by geographic areas are shown in Table 2.

Given the "most likely" timber harvest projections, the average annual volume of this logging residue material available would be 12,920,000 cubic feet. This equals 161,000 oven dry tons of wood fiber (Table 3). Estimated harvesting and hauling

Table 1
Average Net Volume of Wood Residue and Bark Left on Logging Sites
Montana - 1982

Category	All Residue Material	Residue greater than 40% sound	Logging residue in pieces greater than 8 feet long, 4 cubic feet in size, and greater than 40% sound
Cubic Feet of Residue per Thousand Board Feet Scribner of Sawtimber Harvested			
Lodgepole Pine Forest Types	107	100	4
All Other Forest Types	120	110	12

Source: Derived from Howard and Fiedler. These are based on inventories done in 1982. No subsequent estimates have been made; discussion with private and public sector land mangers indicate that in the late 1980s and in the future less large sound material than is shown above would be left on sites because of increased product demand. Less of what is left will be available due to concerns for nontimber resources.

Table 2
Estimated Annual Volume of Logging Residue in Montana
(Pieces Greater than 8 Feet in Length, 4 Cubic Feet in Size and Greater than 40 Percent Sound)
1986-1990

	Northwest	Southwest	North Central	South Central	East	Total
Annual volume of timber harvested (Million Board Feet Scribner)[a]	671	357	76	98	29	1,231
Lodgepole Pine	180	52	34	62	2	330
Other Species	491	305	42	36	27	901
Cubic feet of residue per million board feet Scribner						
Lodgepole Pine	4,000[b]	4,000[c]	4,000[c]	4,000[c]	4,000[c]	4,000[c]
Other Species	19,000[b]	12,000[c]	12,000[c]	12,000[c]	12,000[c]	12,000[c]
Residue available in thousands of cubic feet						
Lodgepole Pine	720	208	136	248	8	1,320
Other Species	9,329	3,660	504	432	324	14,249
All species, total	10,049	3,868	640	680	332	15,569
Total in thousands of oven dry tons	126	48	8	9	4	194

[a] Unpublished data from The University of Montana, Bureau of Business and Economic Research (Missoula, Montana, 1988)

[b] Derived from Keegan, Charles E., III; Timothy P. Jackson, Richard P. Withycombe, Roland L. Barger, Alfred L. Chase. Utilizing Wood Residue for Energy Generation in Northwestern Montana: A Feasibility Assessment. Gen. Tech. Rep. INT-234. U.S. Department of Agriculture, Forest Service, Intermountain Research Station (Ogden, UT, 1987).

[c] Derived from Howard, James O.; Carl E. Fiedler. Estimators and Characteristics of Logging Residue in Montana. Res. Pap. PNW-321. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station (Portland, OR, 1984).

Note: One oven dry ton equals 80 ft^3 solid wood equivalent.

Table 3
Estimated Annual Volume of Logging Residue
(Pieces Greater than 8 Feet in Length, 4 Cubic Feet in Size and Greater than 40 Percent Sound) in Montana
1991-2000

	Northwest	Southwest	North Central	South Central	East	Total
Annual volume of timber harvested (Million Board Feet Scribner)[a]	525	194	89	63	86	957
Lodgepole Pine	89	23	43	42	5	202
Other Species	436	171	46	21	81	755
Cubic feet of residue per million board feet Scribner						
Lodgepole Pine	4,000[b]	4,000[c]	4,000[c]	4,000[c]	4,000[c]	4,000[c]
Other Species	19,000[b]	12,000[c]	12,000[c]	12,000[c]	12,000[c]	12,000[c]
Residue available in thousands of cubic feet						
Lodgepole Pine	356	92	172	168	20	808
Other Species	8,284	2,052	552	252	972	12,112
All species, total	8,640	2,144	724	420	992	12,920
Total in thousands of oven dry tons	**108**	**27**	**9**	**5**	**12**	**161**

Based on timber supply analysis. Note this uses harvested rather than processed.

[a] Unpublished data from The University of Montana, Bureau of Business and Economic Research (Missoula, Montana, 1988)

[b] Derived from Keegan, Charles E., III; Timothy P. Jackson, Richard P. Withycombe, Roland L. Barger, Alfred L. Chase. Utilizing Wood Residue for Energy Generation in Northwestern Montana: A Feasibility Assessment. Gen. Tech. Rep. INT-234. U.S. Department of Agriculture, Forest Service, Intermountain Research Station (Ogden, UT, 1987).

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Note: One oven dry ton equals 80 ft^3 solid wood equivalent.

costs are $60 per oven dry ton for the sites suitable for tractor logging, and $80 per oven dry ton for the sites suitable only for cable systems (derived from Keegan et al. 1987).

Based on information obtained from the land management agencies and timber companies, 80 percent of the timber has been harvested with tractor skidding methods and 20 percent with cable logging systems. Using these proportions, an estimated 155,000 oven dry tons of logging residue were available annually from 1986 to 1990 at an estimated cost of $60 per oven dry ton and 39,000 oven dry tons were available annually at an estimated cost of $80 per oven dry ton (Table 4). Given these proportions, of the total 161,000 oven dry tons of logging residue estimated to be available annually from 1991 to 2000, 129,000 tons would be available at an estimated cost of $60 per oven dry ton (1990 dollars) and 32,000 tons would be available at an estimated cost of $80 per ton (1990 dollars) (Table 5).

Recovery of Cull Portions of Sawtimber Trees

Additional volumes of forest residue are available if cull portions of sawtimber trees remain attached to the sawtimber log rather than being bucked out before being skidded to the landing. The estimated volume of cull sections was based on the volume of green residue material less than 8 feet long and with a small-end diameter greater than 4 inches.

Statewide, from 1986-1990, an estimated 145,000 oven dry tons of this material were available annually (based on estimates made in Keegan et al. 1987, and the harvest levels for the period).

Previous analysis indicates a 15 percent volume loss in this kind of material due to breakage in felling, skidding, loading, hauling, and unloading (Keegan 1981). After an adjustment for defects and breakage, an estimated 123,000 oven dry tons would be available annually from the cull portions of

Table 4
Montana Logging Residue Available Annually Using the Log Length Harvest System 1986-1990

Residue Component	Volume Oven Dry Tons	Cost per Oven Dry Ton (1990 Dollars)
Cull section of saw timber trees	123,000	$30
Large logging residue (> 4 ft3 and > 8 ft in length)		
From tractor sites	155,000	$60
From cable sites	39,000	$80

Table 5

Montana Logging Residue Available Annually Using the Log Length Harvest System 1991-2000

Residue Component	Volume Oven Dry Tons	Cost Per Oven Dry Ton (1990 Dollars)
Cull section of saw timber trees	80,000	$30
Large logging residue (> 4 ft3 and > 8 ft in length)		
From tractor sites	129,000	$60
From cable sites	32,000	$80

sawtimber trees. Cost of recovering this material has been estimated to be $30 per oven dry ton (derived from Keegan et al. 1987).

Table 4 summarizes the estimated annual volume of logging residue recoverable from log-length harvest operations. The largest concentration of logging residue was in the northwestern Montana counties of Flathead, Lincoln, Lake, and Sanders, which, in the past, have supplied 40 to 60 percent of Montana's timber harvest. Given timber harvest projections, 80,000 ODT of this material would be available annually from 1991-2000 (Table 5).

Whole-Tree Recovery

Whole-tree recovery systems appear to offer the greatest potential to supply relatively low cost forest wood fiber in large volumes. The material in this category is primarily limbs and tops of sawtimber trees. Mills receiving sawtimber would probably find whole-tree hauling, and the subsequent processing at the mill, the cheapest source of forest wood fiber.

A large-volume user, independent of a sawmill or plywood plant, might find in-woods processing of whole trees cheaper than hauling them to the plant. An adequate road system to handle chip vans and the capability to fully utilize harvesting and processing equipment would be critical in determining the success of in-woods processing.

Cost and Availability from Whole-Tree Recovery Methods.

The cost of recovering the unmerchantable bole tips and limbs from sawtimber trees is potentially low because felling, limbing, bucking, and skidding costs may be the same or actually lower when a whole-tree operation is substituted for a conventional log-length operation (Hedin 1980, Lavoie 1980, Routhier 1982). A whole tree can generally be moved from the stump to the landing on the logging site for no more money, and perhaps less, than it could cost to move only the logs from that tree. Consequently, the costs of processing the limbs and tops at the landing (or mill) and hauling are the only recovery costs of this material.

Little is known about the costs of recovering bole tips and crown wood in the Inland West. Only limited quantitative information is available on recovery of the material, and the available data generally are from other regions. Further, the existing data on recovery reflect a high level of variation associated with species and the season of year.

The recovery of bole tips and limbs requires a whole-tree processor and a chipper. A whole-tree processor and a chipper are expensive and must be run at relatively high production rates to be cost effective. If enough top and crown wood is available, delimbing, topping, and chipping costs should be low. In fact, for small-diameter sawtimber trees, limbing and bucking costs, using a whole-tree processor at a high level of production, should be considerably lower than the cost of limbing by hand, and could actually result in a cost savings.

On the other hand, if the volume of bole tip and crown wood recovered is low, this equipment's level of use also will be low, and the operating cost per processed unit of wood will be high. Low recovery volumes can greatly increase the cost of recovering this material. A range of costs for recovering bole tip and crown wood has been estimated on the basis of information available on the fixed costs of whole-tree processing systems, and the potential high degree of variation in volume recovery.

In-Woods Versus Mill Site Processing

Moving the bole tips and crowns from the landing to the mill site can be accomplished in two ways. The first is to process in the woods and haul sawlogs and the chipped tops and limbs separately. The second is to haul whole trees to the mill and limb, top, and chip at the mill. The relevant costs of recovering this material, in both cases, are hauling and chipping costs. If a whole-tree hauling approach is used, loading costs also must be considered. This discussion focuses on hauling whole trees to the mill where the sawtimber is to be processed.

Residue Cost and Availability: Whole-Tree Hauling to the Mill Site.

Whole-tree hauling theoretically allows the recovery of a larger volume of wood fiber, at a reasonable cost, than either log-length or in-woods recovery. Because log landing size limitations for whole-tree hauling are not as constraining as they are for in-woods chipping, whole-tree hauling could make the crown portions of sawtimber trees available from virtually all harvest sites. This system has limitations, however, and has not been implemented on a broad scale in Montana.

The assumptions used in estimating the application of whole-tree hauling recovery systems are as follows:

- Whole-tree hauling can be implemented on all sites, but it is limited to trees less than 15 inches in diameter. Above 15 inches it was assumed breakage would be excessive. It was assumed that in Montana 90 percent of the harvest of timber east of the Continental Divide, and 80 percent west of the Continental Divide, is composed of trees under 15 inches.

- Loss due to the breakage of the crown components of sawtimber whole trees, logged and hauled, amounts to 40 percent of the crown components.

A detailed analysis of whole tree recovery indicated that in northwestern Montana, 925 oven dry tons of crown and bole material were potentially available for every million board feet (Scribner Decimal C) of sawtimber harvested (Keegan et al. 1987). This estimate was assumed to apply to the other areas in the state. When applied to the estimated 1,231 million board feet of sawtimber harvested from 1986-1990, this factor indicates that 1.1 million oven dry tons of additional wood fiber were available annually in the form of crowns and unmerchantable bole tips of sawtimber trees. The adjustment for breakage and diameter reduces this volume estimate to 557,000 oven dry tons per year (Table 6).

Given the statewide projected annual timber harvest for 1991-2000 of 957 million board feet, the annual volume of crowns and unmerchantable bole tips of sawtimber trees would be 433,000 oven dry tons. This also should be viewed as an upper limit because tighter timber supplies have increased the use of "topwood" for lumber and chips (Table 7).

In a previous analysis, the estimated costs of recovering wood fiber in the form of top and limb wood were $25 to $55 per one hundred cubic feet or $20 to $45 per oven dry ton in 1984 dollars (Keegan et al. 1987). Expressed in 1990 dollars this is $25 to $55 per oven dry ton. The average cost of recovering this material would be approximately $40 per oven dry ton at the mill site to which the sawtimber was delivered.

Other Components of Forest Residue

Other components of forest residue include material from timber stand improvement projects, old logging slash, dead and cull material on unlogged sites, such as insect-, disease-, and fire-killed timber, and material on non-commercial timberlands.

Timber Stand Improvement

Residue from timber stand improvement projects in the state has two major potential sources: precommercial thinning operations, and conversion of stagnant stands of lodgepole pine to properly stocked stands of seedlings (Keegan and Hearst, 1988). In both cases, the available trees are small (less than 7 inches d.b.h.) and expensive to recover. Although numerous regions in Montana have large acreage suitable for thinning or stand conversion, only northwestern Montana has substantial acreage available for stand conversion. Discussions with land managers indicate that less timber stand improvement will be done in the years from 1991-2000, and the consensus was that thinning could provide very limited volumes of material, particularly for fuel.

The best opportunities to recover large volumes of wood fiber from stand conversion would be in northwestern Montana. At present there are about 75,000 acres of stagnated lodgepole pine in the timber base on the Kootenai National Forest (Park 1984). Other forest ownerships in the area could offer 20,000 to 30,000 additional acres (Montana Department of State Lands 1982). Adjacent national forests have additional acres of stagnated lodgepole pine. Estimates indicate that there are more than 30 oven dry tons of recoverable forest residue per acre in this area (Koch 1988). Total

Table 6

Estimated Annual Amount of Limb and Topwood Available From Whole Tree Hauling of Sawtimber
Montana
1986-1990

	REGION					
	Northwest	West	North Central	South Central	East	Total
Estimated annual volume of sawtimber processed (Million Board Feet Scribner)	671	357	76	98	29	1,231
Oven dry tons of topwood per million board feet Scribner	925	925	925	925	925	925
Thousand oven dry tons of limb and topwood potentially available	621	330	70	91	27	1,139
Limb and topwood after breakage and diameter adjustment (thousands of oven dry tons)	299	158	38	49	13	557

Table 7

Estimated Annual Amount of Limb and Topwood Available From Whole Tree Hauling of Sawtimber Montana 1991-2000

	REGION					
	Northwest	West	North Central	South Central	East	Total
Estimated annual volume of sawtimber harvested (Million Board Feet Scribner)	525	194	89	63	86	957
Oven dry tons of topwood per million board feet Scribner	925	925	925	925	925	925
Thousand oven dry tons of limb and topwood potentially available	486	179	82	58	80	885
Limb and topwood after breakage and diameter adjustment (thousands of oven dry tons)	234	86	44	31	38	433

volume potentially available from stand conversion operations would exceed 2 million oven dry tons.

Koch estimated the cost of recovering this material to be $47.50 per oven dry ton (1988). Not all of this material is available, but Koch suggested that 110,000 oven dry tons of bole wood would be available each year for 20 years. However, much of the stand conversion material is on National Forest lands and because many of these acres are needed to fulfill nontimber resource forest plan objectives, large scale harvesting of stagnated lodgepole pine stands will not be occur.

Old Logging Slash

Besides wood fiber from recently completed logging operations, wood residue is available from logging operations completed in the last 10 to 15 years. In the mid-1970s, large volumes of slash were left behind in the Northern Region of the U.S. Forest Service (U.S. Forest Service 1974). Since the mid-1970s, however, slash treatment has generally kept pace with harvesting operations and large volumes of untreated slash are not available. The inventory of logged-over land completed in 1984 also indicated greatly improved slash disposal (Howard and Fiedler 1984).

Logging slash from earlier years' logging operations generally would be more expensive to recover than from recently logged lands. Old logging slash areas therefore could not be expected to contribute a significant volume of wood fiber.

Other Dead and Cull Timber

There is an enormous quantity of dead and cull green timber in the Northern Rocky Mountains, much of it in stands unlikely to be logged for sawtimber. A large portion of this material is far from roads and scattered, making it expensive to recover. The unit cost of a logging operation depends on the volume per acre to be removed, generally decreasing as more volume per acre is removed. The selective logging of dead and cull green material consequently would be more expensive than the harvesting of the same material in conjunction with a sawtimber harvesting operation in which much larger volumes per acre were harvested. Some selective logging of dead timber does occur in the Northern Rocky Mountains, particularly for firewood and high value products such as house logs.

An infestation of mountain pine beetle in portions of the state has reached epidemic proportions. A 1982 estimate indicated that all lodgepole pine stands over 80 years old and 6 inches in diameter on the Kootenai National Forest will have been infested by the mountain pine beetle by 1992 (U.S. Forest Service). This represents a volume of nearly 3 billion board feet or more than 8 million ODT. The Kootenai National Forest has undertaken a large salvage program aimed at recovering the dead lodgepole pine for lumber. However, because of constraints imposed by accessibility and other resource considerations, the harvest volume has been limited to only a small portion of the dead timber. Given present recovery rates, less than 1/3 of the 3 billion board feet of dead lodgepole pine will be recovered by 1995. At that time much of the pine will have been dead for 5 to 10 years and its potential for lumber will be greatly reduced. Beetle-killed pine could then become a major source of wood fiber for other uses such as fuel. However, as in the case with large scale timber stand conversion, recovery of this material will have to deal with numerous constraints due to concerns about nontimber resources.

During the late 1980s, forest fires burned hundreds of thousands of acres of forest lands in Montana. No assessment has been made to determine the impact of the fires on the availability of timber. It is almost certain, however, that not all of the fire-killed timber can be recovered. As the fire-killed timber deteriorates, it loses its market value for manufacture of solid wood products, so the volume of forest residue available for fuel will increase with of time. Large scale recovery of wood fiber for fuel from public lands would be greatly affected by the many constraints due to concerns for nontimber resources.

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